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Resource and Energy Economics 28 (2006) 215–228
RESOURCE and ENERGY ECONOMICS
www.elsevier.com/locate/ree

The missing piece: Valuing averting behavior for children's ozone exposures

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Available online 15 March 2006

Abstract

Individuals can reduce their exposure to air pollution by reducing the amount of time they spend outdoors. Reducing outdoor time is an example of an averting behavior that should be measured as part of willingness to pay (WTP) for improvements in air quality. In this paper, we estimate parents' WTP to prevent restrictions on a child's outdoor time from a stated-preference (SP) conjoint survey. We combine this WTP measure with an estimate of reductions in time spent outdoors on high-ozone days from an activity-diary study to estimate this averting behavior component of WTP for reductions in ozone pollution.

JEL classification: Q51; Q53

Keywords: Hierarchical Bayes; Mixed logit; Children's environmental health; Revealed preference; Air quality index; Cost of illness

1. Introduction

In theory, the benefits of improvements in air quality can be measured using a variety of methods, including stated-preference (SP) surveys, averting-behavior approaches, or cost-of-illness approaches. In practice, the application of these methods is hampered by difficulties with survey design or a lack of data for estimating key parameters. In this paper, we use a unique data set to provide evidence on the potential magnitude of an important averting behavior related to air pollution—reduced time spent outdoors.

Even at relatively low levels, ground-level ozone is known to cause a number of acute respiratory health effects and has even been associated with short-term mortality (Bell et al.,

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0928-7655/$ – see front matter
doi:10.1016/j.reseneeco.2006.02.002

2004). According to the U.S. Environmental Protection Agency (EPA), active children and asthmatics are two of the most highly susceptible subpopulations. Physically active children are vulnerable because they tend to spend more time outdoors and to breathe faster and deeper. Asthma sufferers are at high risk because their lungs are generally more sensitive to environmental conditions, and ozone is known to trigger asthma-related symptoms.

To protect the public from ozone-related health effects, EPA and organizations such as the American Lung Association recommend that people spend more time indoors and engage in less strenuous activities on relatively high ozone days. In part to assist individuals concerned about ozone conditions, EPA developed the air quality index (AQI). This index combines information about ozone levels (and other pollutants) to produce five categories of air-quality, ranging from good to very unhealthy. To more easily and effectively communicate these conditions to the general public, the five categories are also color coded, ranging from green to purple as shown in Table 1. Forecasted and actual conditions typically are reported to the public daily during high-ozone months through local media outlets, using various versions of this air-quality categorization scheme.

Despite the official policy recommendation to reduce outdoor time, there is little evidence on the extent to which individuals actually reduce their time outdoors, and we know of no studies that attempt to value such reductions in outdoor time. This study combines estimates of the amount by which children's time outdoors is reduced on high ozone days with parents' willingness to pay (WTP) to avoid reductions in their child's outdoor time to provide preliminary evidence on one component of the benefits of improving air quality. Section 2 reviews the literature that examines reductions in outdoor time on high air pollution days and studies that have attempted to measure the value of improving air pollution or medical conditions associated with air pollution. Section 3 presents a cost-of-illness model to measure the value of air-quality improvements. Section 4 describes the study and the characteristics of our panel. Our empirical results are described in Section 5, and we compare our estimates of the monetary value of observed reductions in outdoor time with other environmental-health values in Section 6. Section 7 discusses some implications of our results.

Table 1
Air quality index color code guide

Air quality	Health effects
Good (green)—AQI: 0–50	No health effects are expected
Moderate (yellow)—AQI: 51–100	Unusually sensitive people should consider limiting prolonged outdoor exertion
Unhealthy for sensitive groups (orange)—AQI: 101–150	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion
Unhealthy (red)—AQI: 151–200	Active children and adults, and people with respiratory disease such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
Very unhealthy (purple)—AQI: 201–300	Active children and adults, and people with respiratory disease such as asthma, should avoid all outdoor exertion; everyone else, especially children, should avoid prolonged outdoor exertion

Notes: AQI refers to the air quality index. An AQI of 100 is equivalent to the National Ambient Air Quality Standard (NAAQS). An AQI greater than 100 is considered to be above the national standard or NAAQS. *Source*: U.S. Environmental Protection Agency (EPA, 2002). "Air Quality Guide for Ozone." http://www.epa.gov/airnow/aqguide.pdf.

2. Background

There are relatively few averting-behavior studies related to air-quality improvements. Bresnahan et al. (1997) examine data from a panel of adults in the Los Angeles area and find that individuals do change their behavior in response to poor air quality by reducing time spent outside on a day-to-day basis. Neidell (2004), using a data set that combines individual child asthma-related hospitalization data with zip-code level population demographics, finds a negative, significant relationship between health advisories (proxies for avoidance behavior) and hospitalizations. In a nationally representative survey, over 50% of the respondents who were aware of the color-coded ozone alert system described in Table 1 stated that they reduced the amount of time they spent outdoors on high ozone days (Mansfield and Corey, 2003). Alberini and Krupnick (2000) compare estimates of WTP and cost of illness methods of measuring the benefits of improving air quality in Taiwan. In their data, individuals did not significantly reduce their time outdoors on high-pollution days.

Using a cost-of-illness approach, several studies have attempted to estimate the national costs of asthma attacks, an acute health outcome frequently associated with high levels of ozone pollution (Weiss et al., 1992; Smith et al., 1997). These studies account for direct medical expenditures and indirect costs such as lost income and productivity, but neither study takes into account averting activities taken to avoid an asthma attack. Using an averting-behavior approach, Dickie and Gerking (1991) examined the decision to seek medical care. They found that WTP was two to four times higher than medical cost savings associated with ozone reductions.

Importantly, however, none of these studies has specifically examined behaviors and values related to protecting children from ozone exposure. There are many difficulties involved with estimating benefits for children. Children do not make decisions for themselves and do not have income, thus it is not possible to elicit traditional WTP measures from them. In the place of values elicited from children, researchers typically measure the WTP of parents to protect their children from health risks, often inferring WTP from decisions to purchase market goods that contribute to safety such as cars or bicycle helmets (Schulze et al., 2000; Jenkins et al., 2000). Our study also estimates parents' values, but focuses on nonmarket adjustments to reduce exposures.

3. Averting behavior and WTP

A number of authors have developed theoretical models that relate health to utility. From these models, one can derive a theoretical expression for WTP pollution reductions that lead to better health outcomes. From Freeman (2003) and Harrington and Portney (1987), we present a basic model of health and pollution. Assuming that utility is a function of sick days (S), all other goods (X) and leisure (f), the individual will maximize utility subject to a full-income constraint:

$$\max U(X, f, S) + \lambda(I + P_{\mathrm{w}}(T - f - S) - X - P_{\mathrm{a}}a - P_{\mathrm{b}}b) \tag{1}$$

where b is the medical treatments and mitigating activities, a the averting and avoiding activities, I the non-labor income, P_{w} the wage, T the total time available, P_{a} the price of averting activities, P_{b} the price of mitigating activities, and λ is the Lagrangian multiplier.

Sick days are a function of exposure to pollution (d) and mitigating activities (b) and exposure is a function of the level of pollution (c) and averting activities (a):

$$S = s(d, b) \tag{2}$$

$$d = d(c, a) \tag{3}$$

Marginal WTP for a change in pollution levels is then:

$$W_c = P_w \frac{ds}{dc} + P_b \frac{\partial b^*}{\partial c} - P_a \frac{\partial a^*}{\partial c} - \frac{\frac{\partial u}{\partial s}}{\lambda} \frac{ds}{dc} \tag{4}$$

In Eq. (4), a^* and b^* represent the optimal levels of mitigating and averting activities. WTP is the sum of lost wages (or the opportunity cost of lost time), medical expenses, the change in averting expenditures, and the dollar value of the disutility of illness. Many researchers have discussed the problems associated with calculating WTP for changes in pollution levels from this equation, in part because of the difficulty in estimating each of the components of Eq. (4).

In the case of air pollution, staying indoors is a recommended method to reduce exposure. The difficulty lies in estimating both the chosen reductions in outdoor time and the associated cost of such reductions. Reductions in outdoor time, especially for children, do not typically result in income losses or require the purchase of market goods, although it is possible that parents might pay for such indoor activities as going to a movie or a museum.

Our study provides an estimate of the change in outdoor time on high ozone days $\partial a^*/\partial c$ using data collected from activity diaries administered on high and low ozone days. The shadow price of reducing outdoor time, P_a, is estimated using an SP survey. We describe the study and SP data analysis in the following section.

4. Project design and sample characteristics

Our data for the SP survey come from a larger study of children's activities on high and low ozone days. We conducted a series of eight surveys with a common set of households across the U.S. during the 2002 ozone season. Each panel member completed an initial survey at the beginning of the summer to collect some basic information and explain the activity diaries. After this, each member of the panel was sent six activity diaries. A debriefing survey and SP survey were administered in June 2003. The debriefing survey contained one of two SP choice tasks based on either a medicine commodity or city commodity. In the first question, parents were asked to make trade-offs between medicines that limited the time their children could spend outdoors. The results from this question are described below. Results from a second question, in which respondents were asked to choose between cities with different levels of air quality and cost of living, are not reported here.

The respondents were all members of the Harris Interactive (HI) online market-research panel. The Harris panel consists of individuals who self-select into the panel and have agreed to participate in surveys over the internet. HI recruited the sample for this project and administered the survey over the internet. The panel included families in which, during the summer of 2002, there was a child aged 2–12 years old and at least one parent stayed home with the child during the day. Approximately one-half of the children in our panel had been diagnosed with asthma. Respondents were drawn from the 35 U.S. metropolitan areas with the worst ozone pollution based on rankings calculated from the number of code purple, red, or orange days in 2001 (ALA, 2001).

Our initial sample of survey respondents consisted of 977 parents. Seven hundred and sixty-eight households (79%) of the sample completed at least one useable activity diary. Out of these 768 households, 469 (61%) responded to the debriefing survey. The characteristics of the debriefing sample, which experienced attrition from the full diary sample, generally were not significantly different from the full diary sample. *T*-tests of the differences in means between the two subsamples indicated that most of the differences are not statistically significant. Exceptions include the number of children aged 2–12, child's age, and parent's education level, but even in these cases the differences are small. In the debriefing survey, respondents were randomly assigned to one of the two SP surveys. A total of 231 usable responses to the medicine commodity survey were collected. Table 2 reports demographic characteristics and other summary statistics for the respondents to the Medicine commodity SP survey.

On average, households had about two children and an annual household income of somewhat more than $50,000 (the log of income is reported in Table 2). The mean age for the child whose activities are reported in the diaries was 7 years old (in 2002), and slightly more than half of them were male. As part of the debriefing survey, parents were asked to rate the degree to which their child likes play outdoors versus indoors. The variable "child prefers outside" equals 1 if the parent said that her child always or usually preferred to play outdoors. Approximately 42% of the children in this sample prefer playing outdoors. Slightly less than half the children in the sample have asthma, and 17% have asthma attacks triggered by allergies ("child has allergies and asthma"). Asthma status and preferences for outdoor play were not significantly correlated.

To capture and compare average "historical" conditions in the cities in which respondent households reside, we gathered temperature and AQI data for each city from two previous summers (2000 and 2001). Average summer temperatures ranged from 74 °F (23 °C) in San Diego, CA, to 102 °F (39 °C) in Phoenix–Mesa, AZ. The average number of summer orange and red alert days varied from 5.25 in Chattanooga, TN, to 76.5 in Los Angeles–Riverside–Orange County, CA. The variable "aware" equals 1 if the respondent was aware of the color-coded ozone alert system. Approximately 60% of the sample was aware of the alert system.

Table 2
Stated-preference survey sample characteristics

	Mean	S.D.	Minimum	Maximum
Average summer temperature	85.20	7.21	74.17	102.22
Average number of red and orange alert days	20.52	18.22	5.25	76.50
Child has asthma	0.45	0.47	0	1
Child has allergies and asthma	0.17	0.38	0	1
Number of children	2.08	0.99	1	7
Child age	7.11	3.42	2	12
Child male	0.57	0.50	0	1
Child prefers outside	0.42	0.49	0	1
Aware	0.61	0.47	0	1
West coast	0.19	0.39	0	1
Number of rooms in house	7.06	2.11	2	14
Log of household income	3.97	0.62	1.61	5.52
Number of observations	231			

> Assume that at the beginning of the summer, your family doctor tells you that [child's name] needs to take a medicine during the summer as a preventive measure. In other words, [child's name] is not sick, but [he/she] needs to take medicine to prevent an illness from developing….
>
> [Child's name] would have to limit the time spent outdoors on the days [he/she] takes [his/her] medicine. Even on cloudy days or when [he/she] is wearing sunscreen, extended exposure to the sun will make the medicine less effective.

Fig. 1. Definition of the outdoor time attribute.

5. Analysis of stated-preference data

During episodes of bad air pollution it is recommended that parents restrict their child's outdoor time. Limits on time outdoors impose costs on the child and the parent that may vary by the family's preferences and characteristics. To fully estimate the shadow price of restrictions on outdoor time, P_a from Eq. (4), we conducted an SP survey in which parents were asked to choose between medicines that restricted time outdoors. Like some actual antibiotics, the hypothetical medication requires limited exposure to sunlight. Fig. 1 contains the text that explains this feature of the medication. Table 3 shows the attributes and levels used to construct the choice profiles. The levels for the maximum amount of time outdoors were based on the activity-diary results. On average, children spent less than 1 h totally outdoors per day. Looking across the cities in our sample, the length of time the child takes the medicine was based on the number of red days per summer for a range of cities. Finally, the range of costs was based in part on the range of estimates in the literature of WTP for a symptom-free day.

We employed an adaptation of Zwerina et al. (1996) algorithm to search for a D-optimal experimental design. D-efficiency minimizes the geometric mean of the covariance matrix of the parameters and is the most commonly used criterion for constructing experimental designs (Kanninen, 2002). The experimental design consisted of three attributes, each with three levels. There were 15 unique tradeoff tasks grouped into three blocks; each respondent saw one block of five choice tasks with two alternatives each. Two hundred and thirty-one respondents provided usable data for estimation. Fig. 2 shows an example choice task.

Table 3
Medicine attribute table

Attribute	Levels
Maximum number of minutes in the sun allowed per day	10 min
	45 min
	1 h 30 min
Length of time child takes medicine	3 days
	12 days
	20 days
Total cost of medicine for the summer	$10
	$40
	$75
	$150

Medicine Features	**Medicine A**	**Medicine B**
Number of days [name] would have to take the medicine.	3 days during the summer	12 days during the summer
Maximum recommended outdoor time on days when [name] takes medicine.	45 minutes	10 minutes
Total cost of medicine to you. (The cost not covered by insurance).	$150 for the summer	$10 for the summer
Which medicine would you purchase? (Please check one box.)	***Purchase A*** ☐	***Purchase B*** ☐

Fig. 2. Example choice task.

5.1. Hierarchical Bayes estimation

Following Train and Sonnier (2004) we estimated the choice models using a hierarchical Bayes procedure (Allenby and Rossi, 1999; Sawtooth Software, 1999). We specify the utility for respondent n, alternative j, choice question t as

$$U_{njt} = \beta_n' X_{njt} + \varepsilon_{njt} \tag{5}$$

X is the attribute matrix describing all the profiles in the experimental design, $\varepsilon_{njt} \sim$ iid extreme value and $\beta_n \sim N(b,\Omega)$. Letting y_{nt} indicate the respondent's chosen alternative in question t and conditional onβ_n, the probability of respondent n's sequence of choices is the product of standard logit formulas

$$L(y_n|\beta_n) = \prod_t \frac{\exp(\beta_n' X_{ny_{nt}t})}{\sum_j \exp(\beta_n' X_{njt})} \tag{6}$$

The unconditional choice probability is $L(y_n|\beta_n)$ integrated over all possible values of β_n weighted by the density of β_n:

$$P_n(y_n|b,\Omega) = \int_{-\infty}^{+\infty} L(y_n|\beta_n) g(\beta_n|b,\Omega)\,\mathrm{d}\beta_n \tag{7}$$

where $g(\cdot)$ is the multivariate normal density. This product of logits is mixed over a density of preference parameters and thus is called mixed logit.

Table 4
Mixed logit/hierarchal Bayes estimates (means of individual part-worth estimates)

Medication attribute	Estimate	Standard error
Restricted days	−0.0947***	0.0076
Restricted time	0.0136***	0.0007
Cost	−0.0153***	0.0010

Number of draws for burn-in: 30,000; number of draws on posterior: 20,000; number of draws kept for inference: 2000; likelihood ratio χ^2: 322.8 ($p = 0.000$); Maddala's pseudo-R^2: 0.24; percent correctly predicted choices: 75.6.

The Bayesian algorithm employs 30,000 draws to obtain a ''burn-in'' estimate of the converged population parameters. Simultaneously, the population estimates are adjusted using individual choice data to obtain posterior individual-level parameter estimates. The tenth draws of an additional 20,000 iterations are used for inference. The means and standard deviations of these draws correspond to classical parameter estimates and standard errors. All models reported below use draws on the full multinomial normal.

These latent parameter estimates may be further transformed to incorporate prior information on the support for the underlying distributions. For example, we expect the cost parameter to be negative, so a lognormal or log-odds normal distribution (Johnson, 1949) may be appropriate transformations. The foregoing procedure is unaffected, except that the latent normal parameters are transformed before calculating utility and likelihoods.

5.2. Stated-preference estimates

Based on effects-coded models (not reported here), the effect of the number of days that a child would have to take the medication during the summer has the greatest effect on indirect utility, while cost was next in importance. The least important attribute was the number of minutes that a child would be allowed to play outdoors during a day on which he or she took the medication. Level coefficients are correctly ordered and level coefficient differences are significantly different from one another. Preliminary models ruled out nonlinear effects. Thus, we report estimates here for continuous specifications.

Table 4 contains the means of the individual-level part-worth parameter estimates for the linear model. All parameters are highly significant and have the expected signs. Table 5 reports the WTP point estimates and 90% confidence intervals for no restricted days and 90 min of outdoor play time per day relative to the attribute levels in the experimental design. These WTP values represent the value to parents of easing restrictions on time outdoors for their children. Estimates range between about \$20 for 3 restricted days of 90 min to about \$200 for 20 restricted days of 10 min.

Using the data from the activity diaries and the SP estimates we can calculate the averting-behavior component of total WTP for particular improvements in air quality. Based on regression analysis of the activity diary data for children who spent some time totally outdoors, children in the sample with asthma reduce their time spent totally outdoors by 30 min on a code-red day relative to a code green, yellow, or orange day (Mansfield et al., 2004). Based on the results presented in Table 4, parents are willing to pay \$35.18 (90% C.I. 33.96–36.46) for an additional 30 min of time outdoors on a given day.[1]

[1] Mean of WTP calculated for each respondent based on the coefficients in Table 4 assuming—1 day and 30 min.

Table 5
Mean WTP to avoid restrictions on outdoor play time (relative to no restricted days, 90 min per day)

Restricted days	Restricted minutes per day		
	10	45	90
3	96.03	62.71	19.88
Upper bound	99.46	64.85	20.62
Lower bound	92.71	60.60	19.14
12	155.66	122.34	79.5
Upper bound	160.80	126.42	82.47
Lower bound	150.59	118.41	76.58
20	208.66	175.34	132.5
Upper bound	215.60	181.32	137.44
Lower bound	201.94	169.54	127.63

Fig. 3a–d plot the distributions of the individual-level parameter estimates for days, time, and cost, respectively, as well as averting-behavior WTP. The distributions indicate quite different degrees of preference heterogeneity across attributes. The distributions for days, cost, and WTP are multimodal and roughly symmetric, while the distribution for TIME is unimodal, but skewed somewhat to the left. The variances for days and WTP are relatively large, while the other variances are relatively small.

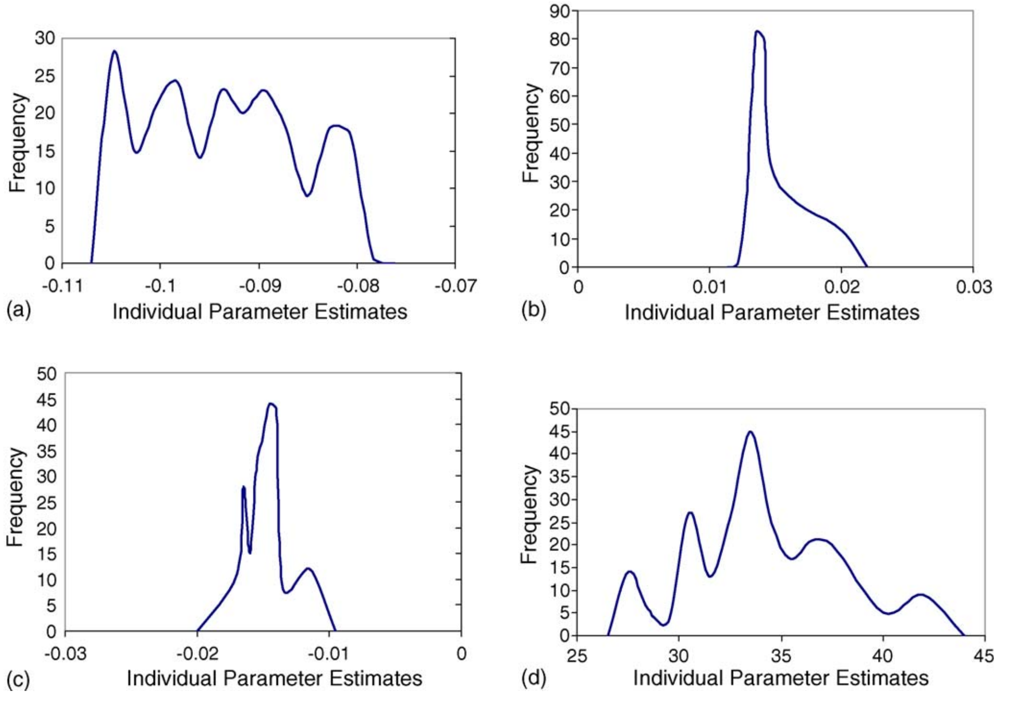

Fig. 3. (a) Distribution of individual-level estimates: days. (b) Distribution of individual-level estimates: time. (c) Distribution of individual-level estimates: cost (d) Distribution of individual-level estimates: WTP.

Table 6
Linear regressions of individual-level parameter estimates and WTP on covariates

Covariate	Days		Time		Cost		WTP	
Constant	−0.092624	−0.093185	0.014407	0.014203	−0.014514	−0.014705	36.3710	35.5547
Child age	−0.000074		−0.000008		0.000018		0.0291	
Average number orange and red days	0.000011	0.000021	−0.000003	−0.000001	−0.000009**	−0.000008**	−0.0234**	−0.0207**
Average summer temperature	0.000079	0.000086	−0.000006	−0.000005	−0.000024**	−0.000022**	−0.0683**	−0.0629**
West coast	0.000227		0.000044		−0.000021		−0.0712	
Child male	0.001435	0.00147	−0.000137	−0.000125	−0.000386***	−0.000387***	−1.1830***	−1.1536***
Aware	−0.001261		−0.000094		0.000094		0.0655	
Child prefers outside	−0.002572**	−0.002431**	0.000007	0.000021	0.000417***	0.000406***	1.0762***	1.0703***
Number of children	0.000742		−0.000001		−0.000095		−0.2363	
Number of rooms in house	−0.000175		−0.000022		−0.000033		−0.1140	
Child has allergies and asthma	0.000461		0.000068		−0.000077		−0.0111	
Child has asthma	−0.000397		0.000041		0.000109		0.3354	
Log of household income	−0.005652*	−0.006654**	0.000036	−0.000073	0.001261***	0.001126***	3.1184**	2.6273**
N	231	231	231	231	231	231	231	231
Adjusted R^2	0.03	0.04	0.00	0.00	0.11	0.12	0.07	0.09

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

Table 6 contains linear regression estimates for models that attempt to explain the individual-level taste heterogeneity indicated in Fig. 3a–d. We report two model specifications for each attribute and WTP. The first model incorporates a full list of potential covariates, while the second model reports corresponding results for a parsimonious specification. Explanatory power of all models is quite low. None of the covariates is significant in explaining the (relatively small) variation in tastes for TIME, and only two covariates, a dummy variable indicating the child prefers to play outside and household income, are significant for days.

In contrast, several covariates are significant in explaining the willingness to trade off cost against the two restriction attributes, as well as WTP. These variables include the average number of orange and red days, average temperature, whether the child is a boy, outside play preferences, and household income. A larger number of high-ozone days and higher summer temperatures decrease WTP, although awareness of ozone alerts is not significant. A preference for outdoor play increases WTP. Holding outdoor play preferences constant, WTP for boys is less than for girls, although both effects are small. WTP for outdoor play time is not affected by whether the child has allergies or asthma. Finally, larger incomes are associated with larger WTP, but the elasticity is only 0.075.

6. Comparisons to other environmental health values

How does our averting-behavior WTP estimate compare with other estimated components of WTP for improvements in air quality? Dickie and Gerking (2002) review six stated preference surveys that attempted to value WTP for reduced morbidity.[2] A number of studies provide estimates of the value of avoiding acute symptoms. Estimates for WTP to avoid a day experiencing one acute symptom (cough, shortness of breath, or a "symptom day") ranges from $0 to $123 ($2001, after adjusting for income differences across the samples) depending on severity of symptoms. Dickie and Messman (2004) is the only study reviewed that provides WTP by parents to relieve a day of acute illness for their child. Reported median WTP (in $2000) range from $128 for one day of mild symptoms to $217 for severe symptoms. They also review four averting-behavior studies that use medical-care expenditures to estimate WTP for an improvement in air quality.[3] The variety of endpoints valued makes comparisons more difficult, but Dickie and Gerking (1991) estimate WTP of $141–$310 (in $2001) per person per year for healthy time from a reduction in ozone levels. The other studies estimated an annual WTP of less than $60.

We can also compare the magnitude of the averting behavior component of WTP for improvements in air quality to the value of medical expenses associated with asthma. Using data from the 1987 NMES, Lozano et al. (1999) examine health care expenditures for U.S. children aged 1–17 years with asthma. They estimate average annual expenditures of $391 ($2003) on asthma care including prescriptions, ambulatory visits, emergency department visits and hospitalizations for the sample. Druss et al. (2001) use the 1996 Medical Expenditure Panel Survey (39% of the study population was under 18 years old) and estimate direct per capital health costs for the treatment of asthma of $863 ($2003) and health costs of $3618 per year including the costs of co-morbid conditions. Yelin et al. (2002) and Cisternas et al. (2003) find similar total costs associated with annual asthma treatment ($3871 and $3902 in $2003). Annual

[2] Studies include Dickie et al. (1986, 1987), Tolley et al. (1986), Johnson et al. (1997, 2000), Loehman et al. (1979), and Dickie and Messman (2004).

[3] Studies include Cropper (1981), Joyce et al. (1989), Gerking and Stanley (1986), and Dickie and Gerking (1991).

costs for prescription medicines (in \$2003) ranged from \$1,970 in Cisternas et al. to \$78 for children in Lozano et al. (1999).

Our activity diary study found that children with asthma spent varied amounts of time outdoors and had varied reactions to high ozone days in terms of decreasing time outdoors. Comparing our estimate of the costs associated with averting behavior compared to WTP to avoid symptoms and healthcare expenditures on asthma, there are clearly children for whom averting behavior is a less costly than a day of symptoms or medication.

7. Discussion

Calculating the full benefits from improvements in air quality requires estimates of averting behaviors and the costs associated with these behaviors. Averting behaviors are difficult to measure and the costs of behaviors like staying indoors are typically unobserved. In this paper, we present estimates of the cost of an important averting behavior, reducing time outdoors, derived from a unique data set that links information on time outdoors with individual values for restrictions on time outdoors. WTP values calculated from our SP survey range from \$20 to \$200, with a marginal value for a 1-day reduction in restricted outdoor time of about \$35. Parents' WTP to reduce restrictions on outdoor time for their children falls within the range of WTP values to avoid a day of acute respiratory symptoms, suggesting that there may be individuals for whom outdoor time is more valuable than avoiding a day of respiratory symptoms.

To a certain extent, we were surprised by both what we consider the relatively modest reductions in outdoor time on days with unhealthy levels of air pollution and the somewhat high values that parents place on relaxing restrictions on outdoor time for their children. Of course, in light of the high WTP for unrestricted outdoor time, the relatively modest behavioral response to red alert days makes sense. The U.S. EPA and organizations like the American Lung Association recommend that individuals restrict time outdoors on high pollution days, and they are interested in promoting greater awareness of the AQI and greater adherence to recommendations for defensive action. The relatively high values for outdoor time measured in our survey suggest it may be difficult to encourage people to take defensive action by staying indoors. Greater publicity of AQI might reduce exposure to air pollutants and healthcare costs, but it would lead to increased averting behavior costs. The unmeasured impact of poor air quality on daily life may represent a significant component of the value of regulations that improve air quality.

Finally, averting behaviors, such as reducing time outdoors on high pollution days, will affect the measured association between air pollutants and outcomes such as hospitalizations or mortality. To the extent that individuals engage in averting behaviors, the impact of air pollutants on health may be underestimated. Understanding the value individuals place on time outdoors, the determinants of WTP for time outdoors and the amount of time spent outdoors will improve studies that attempt to measure the association between air quality and health outcomes.

This study represents a first attempt to determine the shadow price of averting behavior related to children's exposure to ozone pollution. Our study indicates considerable heterogeneity in the values parents place on that time. The results have implications for researchers and policy makers interested in measuring the health impacts of air pollutants and the benefits associated with improvements in air quality. However, this study should be seen as only a first step. We looked at a specific population where we thought it was likely that we would observe averting behavior. The approach used in this study could be extended to other populations and refined to examine in more detail the factors that affect the cost of averting behaviors and responsiveness to public health warnings.

Acknowledgement

This research has been supported by a grant from the EPA's Science to Achieve Results (STAR) program. Although the research described in the article has been funded wholly or in part by the EPA's STAR program through grant (#8295440), it has not been subjected to any EPA review, and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

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